50 per cent of the cases, is succeeded by rising pressure after an interval of 24 hours or less; but in the southern part of the country the number of cases of falling pressure continuing for two consecutive days is decidedly greater than in the north. The details for the months of January and July are shown in Table 2, expressed as percentages of the total number of cases. For example, at Portland, Oreg., the interval was 24 hours or less in 46 per cent of the total number of cases; 48 hours or less in 35 per cent of the cases, etc.

TABLE 2.—*Percentage frequency of the intervals stated, between katallobars at the several stations in January and in July (1894–1903).*

Stations.	JANUARY. Interval in days.							JULY. Interval in days.						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.
Portland, Oreg.	46	35	12	6	0.5	....	0.5	36	36	18	7	3	0.5	....
St. Paul, Minn.	56	32	10	0.5	0.5	0.5	....	50	33	14	2	1	....	....
St. Louis, Mo.	55	23	10	11	2	....	....	30	33	19	12	5	0.5	0.5
Eastport, Me.	56	31	8	2	2	0.5	....	25	44	18	7	6	....	....
San Diego, Cal.	33	37	17	12	0.5	....	0.5	38	39	19	4	....	....	....
New Orleans, La.	32	38	19	10	0.5	....	0.5	30	43	24	3	....	....	....
Key West, Fla.	33	38	16	1	6	5	0.5	32	43	16	9	1	....	....

The greatest number of consecutive days with falling pressure at any of the stations in the United States was seven; a few cases were recorded where the pressure was either stationary or falling for eight and nine consecutive days, but these cases were rare. When the fall was long continued the amount day by day was small, especially at southern stations. One case was noted, however (Eagle, Alaska, from Dec. 14–21, 1899), where the aggregate fall for eight consecutive days was 1.66 inches. This amount in hundredths of inches was distributed as follows: 0.18, 0.37, 0.20, 0.42, 0.13, 0.25, 0.01, and 0.10.

Mean daily accidental variations.—The mean daily accidental pressure fluctuations, in inches of mercury, for the 10 years are given in Table 3. This table clearly shows that the greatest daily accidental changes in pressure are found off the Maine coast. Additional observations in this region would probably show that even greater fluctuations are the rule over the Grand Banks and the continental districts adjacent thereto.

The amplitude of the variations diminishes from north to south in a striking manner.

TABLE 3.—*Mean daily accidental pressure variations for the 10 years 1894–1903.*

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Portland, Oreg.	0.17	0.17	0.18	0.15	0.12	0.10	0.08	0.08	0.11	0.13	0.18	0.17
San Diego, Cal.	.08	.08	.07	.06	.05	.04	.04	.04	.04	.05	.06	.07
St. Paul, Minn.	0.24	0.21	0.23	0.17	0.15	0.12	0.11	0.12	0.16	0.19	0.20	0.23
St. Louis, Mo.	.20	.20	.21	.14	.10	.08	.07	.07	.09	.12	.17	.20
New Orleans, La.	.13	.14	.12	.08	.05	.04	.04	.04	.04	.06	.08	.12
Eastport, Me.	0.33	0.30	0.31	0.20	0.17	0.15	0.13	0.12	0.15	0.23	0.24	0.28
Key West, Fla.	.07	.07	.06	.05	.04	.03	.03	.03	.04	.05	.05	.06

In general we perceive from this study that the accidental pressure fluctuations are somewhat more numerous and of greater amplitude in higher than in lower latitudes, and that, as a corollary, the time interval between successive katallobars increases from north to south. All of this is in harmony with the experience of weather forecasters on the North American Continent.

THE TORNADOES AND WINDSTORMS OF MAY 25–JUNE 6, 1917.[1]

551.515 (73)

By H. C. FRANKENFIELD, Professor of Meteorology.

[Weather Bureau, Washington, D. C., July 20, 1917.]

INTRODUCTION.

During the Spring severe local storms may reasonably be expected over some sections of that portion of the United States lying east of the Rocky Mountains, and the years without such severe storms are rare indeed. The conditions leading up to these unwelcome visitations do not occur in such complete form in any other portion of the Northern Hemisphere, but they are clearly defined and are very largely incident to topography. Examine a map of the globe and it will be seen at once that no other portion of the Northern Hemisphere presents a similar arrangement of wide expanse of relatively warm land with, or open to, warm subtropical and tropical waters to the south and southeast and a limiting mountain wall to the westward. At times when certain systems of pressure distribution prevail over the continental interior warm moisture-laden winds from the south and southeast are carried inland and finally encounter the colder north and northwest winds descending along the eastern slopes of the north-and-south barrier. Given these warm south and southeast winds and the cold north and northwest winds, it is apparent that in the region where they meet, and closely adjacent thereto, great interchanges of heat will occur and give rise to phenomena whose intensity will vary with the degree of contrast in the original conditions.

According to Murray, the word "tornado" is evidently of Spanish or Portuguese origin. Its earlier English spelling was *ternado*, probably a corruption of the Spanish *tronada*, or thunderstorm, while *tornado* may have been an attempt to improve *ternado* by treating it as a derivative of the Spanish *tornar*, to turn or return. This spelling is identified with explanations in which not the thunder, but the turning, shifting, or whirling winds are the main features. The sixteenth century navigators applied the term to the violent thunderstorms of the tropical Atlantic with their torrential rains and sudden violent gusts of wind, but this usage is no longer current in the United States.

By tornado we now mean a violent rotary windstorm of restricted diameter, accompanied by rain, and usually by hail, lightning, and thunder. The air masses whirl with great velocity about a central axis, while the whole storm moves along a narrow path across the country with considerable speed, usually between 40 and 50 miles an hour. The width of the path of greatest violence may vary from a few rods to as much as a mile. The tornado cloud is of a black, or ugly gray-black color and usually, although not always, with one or more pendant, funnel-shaped clouds which may or may not reach the earth. The existence of the funnel cloud is entirely in accord with the theory of the tornado and it is not unreasonable to assume that it is always present, but that in instances where it was not observed the main body of the storm cloud swung too close to the earth, cutting off the pendant, or else it may be invisible in the absolute darkness that frequently attends tornadoes.

Tornadoes almost invariably develop in the southeastern quadrant of an area of low pressure, and they may occur at a distance of a much as two or three hundred miles from the center of the depression, originating as a secondary depression in which the ascent of warm and moist air over a region accompanied by a contraclockwise movement of winds directed spirally inward, plays

[1] Accompanied by Charts XLV–59 to XLV–67, inclusive.

an important rôle. This rapidly gyrating movement of the winds which distinctly characterizes the tornado is responsible for the major portion of its destructiveness. Further elaboration as to the origin and development of the tornado and the reasons therefor need not be entered upon here.

ANTECEDENT WEATHER CONDITIONS.

The spring of 1917 was abnormally cold over the greater portion of the United States, and almost continuously so. As a natural sequence the prevailing pressure distribution was largely of a single type, high to the northward and low to the southward. Most frequently the storm movement was from the southwest to northeast across the central portion of the country, the depressions either moving to the northeastward over the upper Lakes or down the St. Lawrence Valley. This condition of affairs continued through the first week of June, but, as temperatures remained low in the south and southeast until after May 20, there were no severe storm developments previous to that time.

THE TORNADOES.

The tornadoes and heavy wind storms of late May and early June were primarily due to a number of low areas of the Colorado, or southwestern type, which moved northeastward across the interior of the country with such frequency and regularity as to constitute a remarkable series. From May 17 to June 3, inclusive, there were 8 of these disturbances, all well-defined and pronounced in character. Directly after they began to develop and move, temperatures naturally rose to the southward and southeastward with the inflow of southerly winds. The evening weather charts for the days involved are reproduced herewith (Charts XLV–59 to XLV–67), whereon appear also the tracks of the tornadoes. The tracks of the tornadoes and storms so far as they were obtainable are also shown in more detail by figure 1. Although the majority of the storms occurred before 8 p. m., it was thought best to reproduce the evening weather maps which are not ordinarily published. The movements of the centers of the parent cyclones since the preceding morning (8 a. m. map) are shown by solid long arrows.

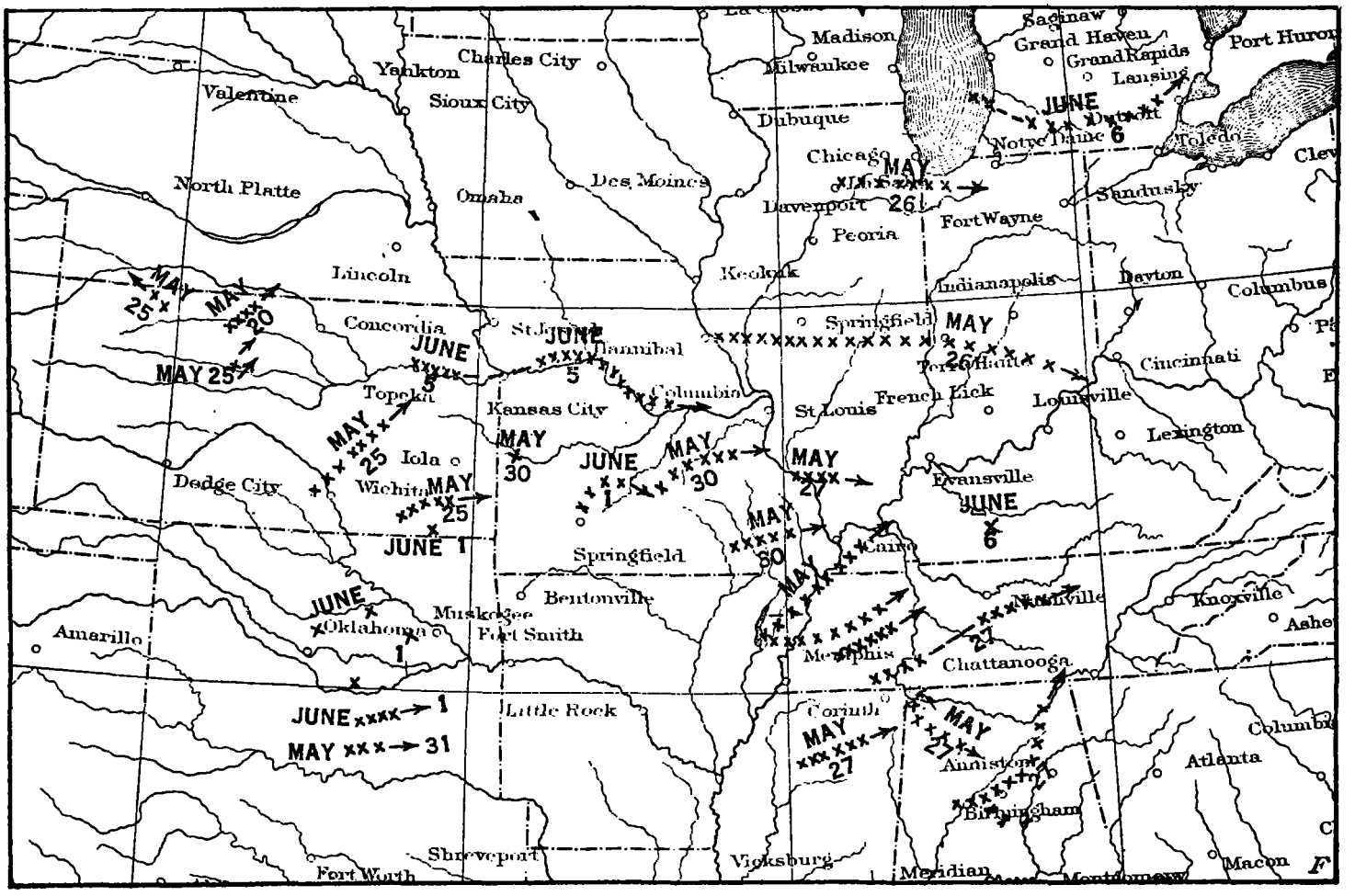


FIG. 1.—Tracks of tornadoes and severe local storms in the Central States, May 20 to June 6, 1917, inclusive.

On the morning of May 20 the second of this series of depressions was central over eastern Colorado with an east-northeastward movement, with cold rain to the northward and northeastward and moderate temperatures to the southward with generally clear weather. Relative humidity was high, ranging from 78 to 95 per cent over southern Kansas and Oklahoma. During the day the disturbance moved eastward, being central at 8 p. m. over southeastern Kansas, and at 6 p. m. the first tornado appeared about 12 miles southwest of the town of Plainville, Rooks County, Kans.

The Kansas storms of May 20.

This tornado moved north-northeastward with a width of track ranging from 200 to 3,500 yards, and in about an hour it had traveled about 35 miles, finally disappearing about 4 miles northeast of the town of Woodston, in the same county. As the approach of the storm could be seen, people sought refuge in caves and cellars, and there was no loss of life. A terrific hailstorm preceded the tornado. At one place the hailstones were 2 inches deep on the level and in another they drifted to the depth of 18 inches, damming the lister rows in recently planted cornfields sufficiently to prevent damage by washing.

It was stated by an eyewitness that the storm center "had the appearance of an immense cone with a diameter of almost 2 miles. At times as many as three funnels would form and then unite into one. While the storm divided the damage was not great, but when the funnels united the effect was terrible."

The detailed statements regarding this storm and those to follow were taken mainly from the special reports of the section directors of the Weather Bureau.

The Kansas storms of May 25.

On the morning of May 25, the third of the series of depressions were central over eastern Colorado, with showers to the eastward and southeastward and a considerable rise in temperature in the Gulf States. Although the usual thunderstorm conditions were present, there were no indications of violent storms in any locality, Relative humidities were high, as afterwards ascertained, 94 per cent at Wichita, Kans., 95 per cent at Oklahoma City, 90 per cent at Little Rock, Ark., 96 per cent at Springfield, Mo., and 94 per cent at Memphis, Tenn, but as the weather was showery these high humidities were without special significance.

The first storm of the day was reported from Decatur County, Kans., at 1 p. m., and it appears to have moved from a point 8 miles northwest of the town of Jennings, to about 10 miles southeast of the town of Oberlin, a distance of about 10 miles in a northwesterly direction. The width of the path varied from 20 to 40 rods and but little damage was done. There was no loss of life.

From its direction of movement this storm could not have been a tornado, but was most likely a direct wind from between northeast and northwest.

About 3 p. m. two small storms formed near Sylvan Grove, in the western portion of Lincoln County, Kans. One was north and the other southeast of the town and both moved in a northeasterly direction. No lives were lost, and the damage was slight. No further details as to the storm were received.

The most destructive storm of the day occurred about the middle of the afternoon. It formed about 2 p. m., 3½ miles northwest of the town of Cheney, near the western edge of Sedgwick County, Kans., passed eastward through Sedgwick and Harvey Counties, and a portion of Butler County, into southeastern Marion County. The total length of the path was about 65 miles, while its width varied from a few rods to more than a mile—about three-fourths of a mile at Andale and about 1¼ miles at Sedgwick, both in Sedgwick County. The storm traveled about 40 miles in the 45 or 50 minutes.

Quoting from the report of Mr. S. P. Peterson, in charge of the Weather Bureau office at Wichita—

The funnel cloud attending the storm was plainly seen near Cheney, near which the storm had its inception. Here it was formed after a rushing together of the clouds, and was suspended, swinging from the main clouds like an elephant's trunk. Seven miles southwest of Andale it had assumed a dumb-bell shape. At Andale, Sedgwick, and a few miles southeast of Peabody, it seems the true funnel was not observed, but rather a dark storm mass, extending down to the ground, probably being half a mile wide at times. Near Florence two trailing pendants were seen at successive intervals.

Twenty-three persons were reported killed by the storm, 12 at Andale, where the local damage was also at its greatest. The total losses were $600,000. Over 100 farmsteads, residences, and business houses were either destroyed or damaged, trees were stripped of their foliage and bark and hundreds were uprooted or broken off. Considerable damage was done also to crops and live stock.

About 6:30 p. m. the last Kansas storm of the day formed about 4 miles west of Howard, Elk County. Without touching the town of Howard it moved northeastward across the southeastern corner of Greenwood County, and thence nearly due eastward across the adjacent sections of Woodson and Wilson Counties to the south central portion of Allen County, where it disappeared near the little town of Leanna. The total length of the path was about 58 miles and its average width one-fourth of a mile. The time consumed by the storm in traveling the 58 miles was apparently about 25 minutes. No funnel-shaped cloud was reported. But one life was lost in this storm, while the damage to farmhouses, barns, live stock, telephone lines, etc., amounted to about $50,000.

During the night of May 25–26 the Colorado disturbance of the previous day moved from Kansas to northwestern Iowa, with a further increase in intensity and with a considerable rise in temperature to the eastward and southward. Relative humidities at 8 a. m., May 26, were high as a rule, but at the same time the weather was cloudy and showery over the great Central valleys, so that the high humidity was without special significance. However, the general aspect of the weather chart was more threatening than on the previous morning.

The Illinois and Indiana tornadoes and windstorms of May 26.

There were two distinct storms, one over the northern and the other over the central portions of the States of Illinois and Indiana. The northern storm, by far the lesser of the two in every way, occurred between 3:10 and 5:56 p. m. It formed in the vicinity of Mendota, La Salle County, Ill., at 3:10 p. m., moved across Kendall and Will Counties to the Indiana boundary, thence across Lake County and much of Porter County, Ind., where it disappeared in the vicinity of Kouts at 5:56 p. m., having traveled 110 miles in 2 hours and 46 minutes, or at the rate of 40 miles an hour. The width of the track varied from one-half mile to 3 miles, but no funnel-shaped cloud was clearly defined. However, there were many of the usual evidences of tornadic action, three lives were lost in Illinois and four in Indiana, while the property loss was about $1,250,000.

Mattoon tornado.—The central storm, which was the most pronounced and destructive of the series, was first observed at noon in the shape of a tornado cloud at Pleasant Hill, about 7 miles from the Mississippi River. From this point it moved almost directly eastward across the counties of Pike, Greene, Macoupin, Montgomery, Christian, Shelby, and Coles as far as Charleston, where it turned a little to the southeastward and then continued to the Indiana line, afterwards crossing the southern portions of the Indiana counties of Vigo, Monroe, Bar-

tholomew, and the northern and central portions of Jennings County, disappearing near the east line of the latter county at 7:20 p. m. The total length of the path was about 300 miles and the average hourly rate of progression of the storm was 40 miles, the same as that of the northern storm. The average width of the path was about one-half mile, but where the damage was greatest the width was only about one-fourth mile. The storm lifted at times, causing little damage to some places in its path. There was a number of witnesses to a funnel cloud with a swinging tail, that appeared to persist almost as far as Mattoon, and also east of Charleston, but none between Mattoon and Charleston, a distance of about 10 miles, and covering the area of greatest destructive effect. However, there were plenty of convincing evidences of tornadic action over this 10 miles of territory, with a very low and very black cloud mass, and, as suggested by Mr. Root, of the Weather Bureau office at Springfield, the cloud may have been so close to the earth that there was no room for the pendant.

One hundred and one lives were lost during the storm and the property loss amounted to $2,200,000, exclusive of crop losses in the State of Indiana. It appeared that no lives were lost in central Indiana.

A detailed account of the storm will be found in the monthly report of Climatological Data (Illinois section), for May, 1917, which was compiled by Section Director Clarence J. Root, who personally visited the central Illinois district immediately after the storm. It is regretted that want of space prevents the reproduction of more than two of the photographs furnished (figs. 2 and 3). Another interesting account of the tornado by Prof. J. P. Carey, of the Eastern Illinois Normal School at Charleston, will be found in Science for June 15, 1917.

At 8 p. m., May 26, the disturbance that had caused the storm, was centered over Illinois with diminishing intensity, but another of the same general type was centered over the Texas Panhandle. On the morning of May 27 it was over Oklahoma with cloudy weather and moderate temperatures to the eastward and southward, the isobaric and isothermal arrangement indicating an excellent thunderstorm type, but less threatening than that area of the preceding storm.

Storms of May 27 in Arkansas, Tennessee, Kentucky, southern Illinois, northern Mississippi, and Alabama.

Arkansas and Kentucky.—The first severe storm of the day occurred in Mississippi County, in extreme northeastern Arkansas. There were two storms, one forming about 3 p. m. near Archillion, and the other about 4:30 p. m. near Manila. The latter storm moved northeastward over Big Lake, where it disappeared after a journey of only a few miles. The width of the path of greatest destruction was about one-fourth of a mile, and six persons were killed, with a property loss of about $12,500.

The first storm moved northeastward in an irregular course and soon came to the Mississippi River, about 15 miles distant. The rate of progression was slow, and the width of the path varied from one-eighth to one-fourth of a mile. Twelve persons were killed, and the property loss was about $43,000. This storm crossed the Mississippi River apparently quite close to and a little north of the town of Tomato, Ark., and then divided into two storms, one moving almost directly north-northeastward along the left bank of the river, crossing the Tennessee-Kentucky line into Fulton County, Ky., thence through Hickman and Carlisle Counties and the northern portion of Graves County to about the McCracken County line. It is reported that during its passage along the Mississippi River the storm caused a wave or wall of water that appeared to be about 40 feet in height.

The total length of the path of this storm was about 105 miles, of which 90 miles were east of the Mississippi River. The rate of travel from Archillion, Ark., to Hickman, Ky., was about 45 miles an hour. No details as to exact times of occurrence were received from points beyond Hickman, except that the storm passed to the northwest of Mayfield, in Graves County, between 5 and 6 p. m., indicating that the rate of 45 miles an hour was sustained throughout the life of the storm. The width of the path varied from about 100 yards to about one-half mile, least in the vicinity of Clinton in Hickman County.

The funnel-shaped cloud was reported generally in Fulton, Hickman, and Carlisle Counties, Ky., and at Hickman it was said to have resembled a large hornet's nest or balloon. About 60 persons were killed, while the damage amounted to more than $1,000,000.

Tennessee.—The storms in western Tennessee were apparently redevelopments, or offshoots, of the original storm that began about 3 p. m., near Archillion, Ark., and they were four in number. The first one occurred about 4 p. m. in the northwest corner of Lake County, on the Mississippi River, the same storm that devastated the extreme western counties of Kentucky, and two persons were killed, with property damage amounting to $10,000.

The second storm was also an offshoot from the Arkansas storm, and it was first observed near Unionville, 8 miles west-southwest of Dyersburg. The storm reached South Dyersburg about 4 p. m., moving in an east-northeast direction, passing a mile or two south of Sharon, in Weakley County, about 4:30 p. m., and disappeared in the northwestern portion of Henry County. The length of the storm path within the State of Tennessee was about 80 miles, or about 95 miles from the point of origin in Arkansas. The rate of progression of the storm between South Dyersburg, in Dyer County, and Ore Spring, in Weakley County, was about 48 miles an hour, and this was approximately the rate for the entire storm, as it consumed about two hours from start to finish. The average width of the track was one-half mile. Eleven persons were killed by the storm, and the property loss and damage amounted to more than $125,000. Near South Dyersburg a tract of timber valued at $10,000 was almost a total ruin.

The third storm was first noted at 4 p. m. at Trenton, Gibson County, coming from the west, and not far to the southeastward of the second storm, whose course it paralleled. Apparently this storm was also an offshoot from the parent Arkansas storm. The storm track was about 90 miles in length within the State of Tennessee, about 10 miles longer than that of the second storm. No details as to time of occurrence and width of track have been reported other than the time of occurrence at Trenton. Four persons were killed, and the property loss and damage amounted to more than $50,000.

The fourth storm was first observed about 6 p. m. at Finger, in the extreme northern portion of McNairy County. It moved in a northeasterly direction through the southeastern portion of Henderson County, reaching the town of Linden, in Perry County, about 7 p. m., or at the rate of 45 miles an hour. Between Perry and Davidson Counties there were no reports of severe storms, and,

FIG. 2.—View at Mattoon, Ill. showing clearly defined track of complete destruction made by the tornado of May 26, 1917.

FIG. 3.—View at Mattoon, Ill. after tornado of May 26 1917. Taken near the background of Fig 2, and at the side of the track there shown. (Arrows indicate same chimney in both views.

as stated by Mr. Roscoe Nunn, of the Weather Bureau office at Nashville, Tenn., the storm was temporarily deflected. Mr. Nunn says:

> It is probable that after passing Linden it (the storm) was deflected upward by the Western Highland Rim, which extends in a north-south direction across Hickman and Lewis Counties. This is assumed from the fact that it was not so violent in these counties, but became more destructive on reaching the eastern part of Davidson County, where it seemed to come to the earth again, passing just north of Brentwood in an east-northeasterly direction through Bakerton and Una, thence through Dodoburg and Lebanon, Wilson County.

The total length of the storm path was about 140 miles, and the time of travel from Finger to Lebanon 2 hours and 45 minutes, or at the rate of 50 miles an hour.

The first section of the fourth storm resulted in five deaths and property loss to the amount of about $35,000. The second section killed two persons, while the property loss amounted to more than $200,000. At Dodoburg a large poplar grove, valued at $30,000, was destroyed.

No funnel-shaped clouds were reported from any of these four Tennessee storms, although it was stated that wherever any great damage was done the characteristic tornadic phenomena were in evidence. When the third storm passed over Trezevant, Carroll County, at 5 p. m., it was reported that the sun was shining, with the main cloud not more than 150 feet in height, and there was no rain. During the progress of the fourth storm the home of Miss Maggie Moran at Una, Davidson County, was wrecked, and Miss Moran has written that—

> The door was blown open: I tried to shut it, but couldn't, and about that time the roof and north wall were blown northward and I was hurled to the floor; only a second, and the wind turned and blew the rest of the kitchen away, and I was blown 15 feet from the kitchen in a southwesterly direction. One foot was caught between two logs, which were supposed to come from a tree which was blown down near me; the shoe on the other foot has never been found.

Illinois.—The southern Illinois storms of May 27 appear to have been local ones, yet they were doubtless caused by the operation of the same general conditions that caused those to the southward. At 8 p. m. the principal cyclonic center was over southeastern Missouri, indicating that at about 5 p. m., when the southern Illinois storms began, it was central over south-central Missouri, bringing the storm section on its east-southeastern edge. The storm was first observed at 5 p. m., a few miles east of Chester, Randolph County, where it blew down buildings and killed one man. It first moved a little north of east, and at 5:40 p. m. struck the town of Willisville in true tornadic form, with a funnel-shaped cloud. Thereafter the path was a little to the south of east and about 6:30 p. m. there was also some damage at Hallidayboro, in the northern portion of Jackson County. The total length of the path was thus about 30 miles, and the damage amounted to something more than $80,000.

Mississippi.—The storms in Mississippi were not of a very violent character, although at some places reaching the proportions of a true tornado. No lives were lost, and the damage amounted to about $20,000. Except in Pontotoc County, there were evidently nothing more than "straight-line" winds. In Pontotoc County, as reported by Dr. C. W. Bolton, cooperative observer at the town of Pontotoc, there was "a very black cloud, like smoke from a burning sedge field, blowing along the ground, as if boiling. Trees in the center of the path were blown eastward, but on either side toward the center." The postmaster at Sherman, in the northeastern corner of Pontotoc County, reported a funnel cloud, with the direction of the fallen trees north and south of the path the same as at Pontotoc, while at the center there were as many as 12 trees with their tops together.

The storm began about 5 p. m., one hour later than the third Tennessee storm, first appearing near Grenada, in Grenada County. There was "a heavy cloud, but not a well-defined funnel, and the wind was rather straight to the east." The storm moved northeastward, apparently lifting as it passed over Calhoun County, but descending again in Pontotoc County, which it crossed from southwest to northeast, and then disappeared. The length of the track was about 65 miles, while the width varied from 100 yards at starting to one-half mile at the east end of Pontotoc County where it was lost.

Alabama.—The Alabama storms were among the most destructive of the series, and in respect to loss of life they were exceeded only by those of Illinois and Kentucky. The most severe storms occurred in western Walker, northern Jefferson, southern Blount, southeastern Talladega, and southeastern Madison Counties, and they were most destructive in northern Jefferson, where whole mining towns were wiped out. There were also storms of lesser violence in portions of Lauderdale, Franklin, Tuscaloosa, Bibb, Shelby, Etowah, Marshall, and Jackson Counties, all in the northern portion of the State. In all 40 persons were killed, while the losses and damage amounted to more than $430,000.

At 8:45 p. m., a storm moving from southwest toward northeast struck the town of Carbon Hill, in western Walker County. It was accompanied by a funnel-shaped cloud, and cut a path about three blocks wide. Felled trees on the north side of the path pointed toward the southeast, and those in the center and on the south side toward the northeast. Five persons were killed, and the damage amounted to about $200,000. In a short time the storm had moved eastward across Walker County to the northern portion of the adjoining county of Jefferson, or perhaps it would be more exact to say that another storm struck the town of Sayre, in northwestern Jefferson County, at the same time that the Carbon Hill storm occurred. The direction of movement was the same and there was a funnel cloud. The path was about one-half mile in width, and felled trees lay in all directions. The town was obliterated, and nine persons lost their lives, with a property loss amounting to about $65,000. The neighboring town of Bradford was also visited, and 17 negroes were reported killed.

At 9:20 p. m. the little mining town of Majestic, in north Jefferson County, was destroyed. There were no details given, except that there was very little rain. No lives were lost. At the same time the storm reached Village Springs, Blount County, a little to the northeast of Sayre, with the funnel cloud still present. The arrangement of felled trees again indicated the true tornado, those in the center lying with their tops toward the east. A negro infant was killed, while the property loss amounted to about $40,000.

The town of Sylacauga, in southeastern Talladega County, was struck at 12:45 a. m., May 28. There was a well-defined pendant, funnel cloud, and the width of the path was somewhat more than 1 mile. One negro man was killed, and the property loss amounted to about $125,000.

In the town of New Hope, in southeastern Madison County, six persons were killed. No other details were available. The storm also crossed a portion of Tuscaloosa County into Bibb County, and one person was killed at Bibbville, in the latter county.

Details as to the storm conditions in the other counties mentioned were not received.

The Missouri storms of May 30.

On the morning of May 30 another of the series of southwestern disturbances was central over Kansas and Oklahoma, with moderately high pressure and quite low temperatures over the Northwest, and with moderately high temperatures to the southward and southeastward, the surface inversion extending up into the upper Mississippi Valley. General thunderstorms had occurred over the region of the higher temperatures, but conditions were not decidedly abnormal except as to the northwestern low temperatures.

The details received regarding the local storms of the day were very meager, except for the eastern portion of Washington County, but it appears that the first storm was seen in the early afternoon in the vicinity of Houston, Texas County, and that it moved in a northeast-east direction across Dent County, the northern portion of Iron County, and the central and northern portions of Washington and St. François Counties, a distance of perhaps 80 miles. Mineral Point, in Washington County, apparently near the end of the track and the seat of the greatest destruction, was reached at 3 p. m. A funnel cloud was observed here, and the storm lasted about five minutes. Fifteen persons were killed at various places within the storm area, and the property loss probably amounted to more than $500,000, of which about $400,000 was incurred in Mineral Point and vicinity.

Another severe storm occurred in the late afternoon a little farther to the southeastward, originating apparently in the southwestern portion of Wayne County. It moved eastward across the southern portions of Bollinger and Cape Girardeau Counties, and the northern portions of Stoddard and Scott Counties, crossed the Mississippi River a short distance above Cairo, Ill., and passed over the northern portion of Alexander County during the early evening, covering in all a distance of about 85 miles. Here again details are wanting, but press reports stated that 25 persons were killed and much property damaged.

A storm also struck portions of Bates County in the extreme west-central portion of the State during the early morning, doing considerable local damage. It appears from this that the general storm condition consumed a period of about 12 hours in traversing the State from west to east, keeping well to the southeastward of the center of the main barometric disturbance, which at 8 p. m. was over Iowa and northern Missouri.

Storms of May 31–June 1 in Oklahoma and Kansas.

Oklahoma.—On the evening of May 31 the next of the series of southwestern disturbances was central over western Texas, with high pressure, low temperatures, and sharp temperature gradients to the northward, with cloudy weather, and with high temperatures to the southward and southeastward with generally clear weather. The conditions were decidedly unstable and late at night a severe storm broke over Pitman, Love County, Okla., and probably extended eastward over Marshall County, as it was reported at 9 p. m. at Durant in the western portion of Bryan County, where it did considerable damage. Three persons were killed at Pitman, and the general property damage amounted to more than $50,000. The length of the storm track was about 50 miles, and there were some evidences of true tornadic action.

On the morning of June 1 the general disturbance was central over southwestern Oklahoma, with continued high pressure and low temperatures to the northward, and warm, showery weather to the eastward and southward. Conditions were still very unstable and during the day a series of severe storms occurred over various portions of east-central Oklahoma. They began about 2 p. m. in Logan County, and also visited portions of Murray, Seminole, Creek, and Okmulgee Counties, reaching the latter late in the day and destroying 42 oil derricks. Twenty-five derricks were also destroyed in the northwestern portion of Creek County.

In Logan County there were five small tornadoes between 2 and 3 p. m., but their approach was easily visible, and no person was killed or injured. Damage was mainly confined to crops.

Another of the tornadoes visited the town of Drake, in Murray County, at 3:15 p. m., killing 5 persons and doing much damage. This storm moved a little north of eastward and shortly after 4 p. m. struck the town of Coalgate, in Coal County, where it caused the death of 5 persons and ruined property to the value of $500,000. This storm evidently dissipated a short distance east of Coalgate, and the length of the path was about 50 miles. No funnel cloud was observed, but there were many evidences of decided tornadic action, especially at Coalgate, where a "twisting pillar of cloud," about 3 miles in height and ending in a cloud of greenish tint, passed through the western end of the town. The width of the path of the storm from Drake to Coalgate varied from 40 to 150 yards.

In the late afternoon another storm struck the northern portion of Seminole County, doing considerable damage.

Kansas.—The storm field also extended over the Oklahoma-Kansas line, and at 5:30 p. m. the city of Coffeyville, Kans., experienced a storm that tore a path about one block in width through the city. Three persons were reported killed and the property loss amounted to $150,000.

Still another storm visited Franklin and Johnson Counties, Kans., beginning about 6:30 p. m., and three persons were killed near Morse, about 5 miles southeast of Olathe. The storm path was about 200 feet in width and it extended eastward a few miles to the town of Stanley, thence northeastward across the Kansas-Missouri line, where very heavy rains occurred. There was no funnel cloud reported, although there were some slight evidences of tornadic action. The loss and damage amounted to about $10,000.

It was reported also that severe storms had occurred over portions of Greene, Dallas, and Laclede Counties in southwestern Missouri, but no details were available.

Kansas and Missouri storms of June 5.

On the morning of June 5 still another of the southwestern series of storms was over south-central Kansas with an apparent northeastward movement. There was no high pressure to the northward and temperatures had risen over that section. To the eastward and southward there had been heavy showers from the preceding disturbance, while to the southward and southeastward the weather was clear and moderately warm. Conditions were really less threatening than during any of the preceding storms of the series, except that the disturbance was increasing in intensity with its northeastward movement, evidences of a still further increase which was strongly in evidence at 8 p. m. when the storm center was very close to Kansas City, Mo.

Kansas.—The tornado first appeared as a terrific hailstorm at Eskridge, in the southeastern portion of Wa-

baunsee County, Kans., and some of the hailstones were reported to have been more than 3 inches in diameter, actually doing more damage than the tornado that followed a few minutes later. The storm moved eastward across Shawnee County, striking the towns of Valencia, Maple Hill, and Elmont, completely demolishing the latter, but fortunately without loss of life. It was said that the storm lifted and descended several times, and at 5:30 p. m. it reached to within 3 miles of Lawrence, in Douglas County, en route passing through the town of Clinton, 12 miles to the westward, where it killed one man. A section of Jefferson County was also visited. Thus far the length of the storm path was about 50 miles and its width about 1 mile. No funnel cloud was seen, but there were the huge black tornado clouds that gave warning of the approach of the storm. Six persons were killed, while the damage to property and crops was estimated at more than $1,000,000, making the storm by far the most destructive one of the year.

It happened also that at 6 p. m. there was a local tornado 1 mile from Savonburg, in the southeastern portion of Allen County, some 80 miles south of Lawrence. The storm came from the southwest, moved in a northeasterly direction, and evidently soon dissipated. One woman was killed, and the damage to farm buildings, crops, and other property was very extensive.

Missouri.—The northern storm appeared to lose much of its intensity after leaving Douglas County, and, for a time, left no traces, but it apparently crossed the Missouri River just above Kansas City, for in a few hours it appeared in the southern portion of Ray County, Mo., whence it moved northeastward across Carroll County, virtually wrecking the town of Deer Lake at 9 p. m. In the county of Chariton, adjoining to the eastward, the town of Whitham was demolished. After leaving Chariton County, the storm turned to the southeastward, following the general course of the Missouri River. Howard County was passed without much damage, but Boone County was not so fortunate, as there was a redevelopment of a destructive character. The towns of Centralia and New Providence specially suffered, 7 persons losing their lives at the former place.

The length of the active storm path in the State of Missouri from Ray to Boone Counties was about 110 miles, while the distance from the region of cessation from violent storm activity in Kansas to that of its resumption in Missouri was about 65 miles, making the total length of the path about 225 miles. The width of the path within the State of Missouri varied from 50 to 500 feet, and in all 14 persons lost their lives, while the property loss was probably $200,000, of which $100,000 fell upon Boone County.

The usual black clouds were seen, but without the funnel shape. Judging from its behavior, the storm was certainly a tornado. A small iron bridge was carried about 2,000 feet and deposited in a wheat field, a cemetery was swept clear of tombstones, and fields of wheat and corn were swept bare.

There was also a local storm about the same time in the southeastern portion of the Wright County apple belt. No details were received, but press dispatches stated that 7 persons were killed and much damage done.

The Michigan and Kentucky storms of June 6.

During the early afternoon hours of June 6 destructive tornadoes visited several counties in the southern portion of the State of Michigan, killing 3 persons, fatally injuring 5 others, and doing damage to the extent of $1,500,000, one-third of which occurred in the city of Battle Creek, and another third in Washtenaw County. Published details were very meager as to the behavior of the storm, but quite elaborate as to injuries and damage. More complete information will probably be found in the Report of Climatological Data for Michigan for June, 1917.

The weather map at 8 a. m. showed the southwestern disturbance of the previous day to be central over northern Iowa, still moving northeastward with greatly increased intensity (29.12 inches at Charles City, Iowa), accompanied by moderately high pressure and high temperatures on the southeast, and a strong temperature inversion extending northward to southern Lake Michigan. Heavy thunderstorms had occurred in the great Central valleys, the southern Upper Lakes and the western Lower Lakes regions, and on the previous evening there had been tornadoes in eastern Kansas and central Missouri.

Michigan.—The first evidences of unusual storm conditions were noted on Lake Michigan, near Grand Haven, shortly after noon when the crew of the tug *Robert Johnston* saw a waterspout form far out on the lake and sweep toward shore. Fishermen had previously reported the weather out on the lake as very squally. The spout struck the shore hills several miles south of Grand Haven, and as the storm passed inland it developed tornado strength and characteristics, moving to the middle sections of Ottawa County and causing considerable damage to farmhouses and other farm property. About the same time the principal storm of the day first appeared near the town of Climax in the extreme east-central portion of Kalamazoo County. It moved northeastward, soon reaching the city of Battle Creek, Calhoun County, where 28 houses were wrecked and 50 others badly damaged, although no loss of life occurred. After leaving Battle Creek the storm traveled eastward, reaching the town of Springport, Jackson County, about 12:30 p. m. "with a noise like a train coming." Here one person was killed and property destroyed or damaged to the extent of $100,000. The storm continued through the northern portions of Jackson and Washtenaw Counties with undiminished violence, wrecking nearly everything in its path, especially in the extreme northeastern portion of Washtenaw County where 2 people were killed near the town of Salem. Passing into Oakland County, the storm was lost on the waters of Cass Lake after having traversed a path about 105 miles in length. The average width of the path was about one-fourth of a mile, although it is said to have been much less in Battle Creek. The rate of progression was about 40 miles an hour.

Funnel-shaped clouds "twisting back and forth" were reported at different places along the course and also "many black clouds, like smoke," indicating that the storm cloud was very close to the earth. Press accounts of damage also indicated the true tornadic character of the storm.

Kentucky.—During the same afternoon a local storm occurred at the mining town of Bevier, Muhlenberg County, Ky., killing 5 persons and destroying considerable property. The storm moved in a southeasterly direction and crossed Green River a short distance above the town of Rochester, after which it was lost. The crossing of Green River was witnessed by the passengers and crew of the steamboat *Bowling Green*, who reported logs and portions of trees flying through the air. Other reports stated that some trees were blown down and the tops of others twisted off and blown away.

Summary of losses by tornadoes, etc., May and June, 1917.

The losses of life and property follow in tabulated form, by States.

State.	Date.	Lives.	Property.
Kansas	May 20	24	$650,000
Northern Illinois	May 26	1	800,000
Northern Indiana	do	6	400,000
Central Illinois	do	101	2,200,000
Central Indiana	do		300,000
Arkansas	May 27	18	55,500
Kentucky	do	60	1,000,000
Tennessee	do	24	420,000
Alabama	do	40	430,000
Mississippi	do		20,000
Missouri	May 30	40	500,000
Oklahoma	May 31-June 1	8	550,000
Kansas	June 1	6	160,000
Kansas	June 5	8	1,000,000
Missouri	do	14	200,000
Michigan	June 6	5	1,500,000
Kentucky	do	5	
Total		360	10,185,000

While these storms of 17 days were quite numerous, it does not appear that occurrences of this character are increasing in number as a whole, nor is there any special region of greatest frequency. The whole question is one of the occurrence of the contributing distribution of pressure, temperature, and moisture, and certainly the observation and experience of the past do not warrant the conclusion that any one *limited* area more than another within the severe storm field is more subject to the requisite distribution of the formative causes. It can also be said with reference to increasing frequency that the storms are not more numerous than heretofore; but as former sparsely settled districts become more densely populated and facilities for intercommunication become multiplied, the details of the storms are made available more rapidly and losses of life and property increase, because there are more of both exposed to the fury of these unpreventable storms.[2]

METEOROLOGICAL COURSES FOR AERONAUTICAL ENGINEERS.

The National Advisory Committee for Aeronautics, cooperating with the United States War Department, arranged in May, 1917, with a number of leading universities and schools, for courses designed to specially further the education and training of aviators. These courses, technically known as "Ground Schools in Military Aeronautics," include such subjects as elementary meteorology, astronomy, engineering, internal-combustion engines, etc., and they are now being offered at the following institutions: Massachusetts Institute of Technology in cooperation with Harvard University (Cambridge, Mass.), Princeton University (Princeton, N. J.), Cornell University (Ithaca, N. Y.), Ohio State University, (Columbus, Ohio), University of Illinois (Champaign, Ill.), University of Texas (Austin, Tex.), University of California (Berkeley, Cal.).

Prof. Robert De C. Ward is giving the course in meteorology at the Massachusetts Institute of Technology, and also a more extended course forming part of the requirements leading to the degree of aeronautical engineer. He has kindly communicated the syllabus of the longer course and permits us to publish it here, as it is sure to prove helpful and stimulating to others who may have similar tasks assigned them.—*Chief of Bureau.*

[2] For an article on tornado insurance, which discusses frequency in the several States up to and including 1896, see this REVIEW for December, 1905, 33:534-539; see also Flora in this REVIEW, December, 1915, 43:615-616, for statistics on Kansas, including 1915.—C. A., jr.

SYLLABUS OF LECTURES ON METEOROLOGY GIVEN IN THE COURSE IN AERONAUTICAL ENGINEERING AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY IN COOPERATION WITH HARVARD UNIVERSITY.

I.

Ten lectures by Robert De C. Ward, Professor of Climatology, Harvard University.

Introductory.—Importance of meteorology in aviation; aircraft and weather in war:

(*a*) General climate.

(*b*) Weather and weather forecasts; military field meteorological services.

The atmosphere.—Composition; height; "troposphere" and "stratosphere"—general characteristics of each.

Temperatures in the free air.—Vertical temperature gradients; temperatures at various heights; inversions; stable and unstable conditions in relation to flying.

Pressure.—Importance; comparison with water; decrease with altitude; physiological effects of diminished pressure; measurement; mercurial and aneroid barometers and barographs: use, errors, corrections; determination of altitudes by means of barometers; isobars; pressure gradients.

The wind in relation to pressure at earth's surface.—Wind direction; deflection of winds from gradient; Earth's rotation and friction; cyclonic and anticyclonic wind systems; "Gradient wind"; Buys Ballot's Law; isobaric types.—Wind velocity; general relation to gradient; Beaufort Scale and its equivalents in force and in velocity in miles an hour; anemometers: Robinson and Dines; gustiness of wind.

Conditions of the atmosphere affecting aviation.—General and local.—(*a*) General air movements, essentially horizontal; atmospheric layers and waves. (*b*) Local convectional currents, essentially vertical, due to thermal controls: causes and conditions. (*c*) Effects of topography upon air movements, combining both horizontal and vertical elements, due to mechanical controls: effects of friction, topography, and character of surface; vertical and horizontal movements in general in relation to flight.

Weather forecasting.—Explanation of daily weather map; principles of forecasting explained by reference to type maps, for United States and for Europe; general characteristics of cyclones and anticyclones; tracks; velocities of progression.

Noninstrumental local forecasts.—Barometric tendency; veering and backing winds; changes in wind velocity; weather proverbs.

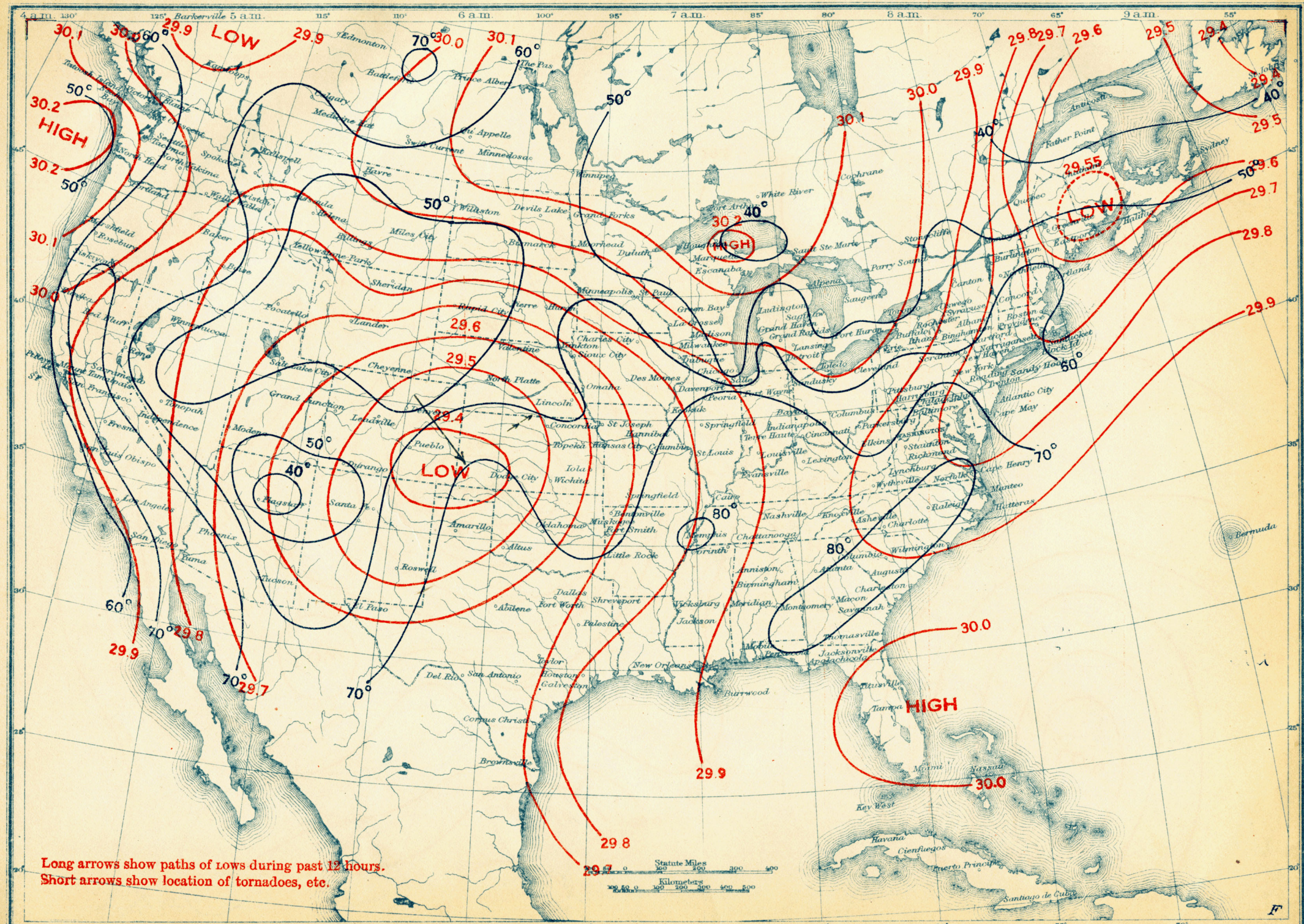
Clouds.—Types; cloud classification; methods of determining cloud heights and velocities, and results; value as weather prognostics; fair and wet weather clouds; fog; special consideration of cumulus and cumulo-nimbus.

Forecasts of wind velocity and direction aloft.—Direct observation by means of pilot balloons, kites, and cloud movements; directions of cloud movements in cyclonic and anticyclonic systems in the United States and in Europe; estimates based on surface conditions and on general knowledge of upper air currents; "Gradient wind"; diurnal variation in wind velocity and direction; changes due to progression of cyclones and anticyclones; wind and cloud directions and night flying.

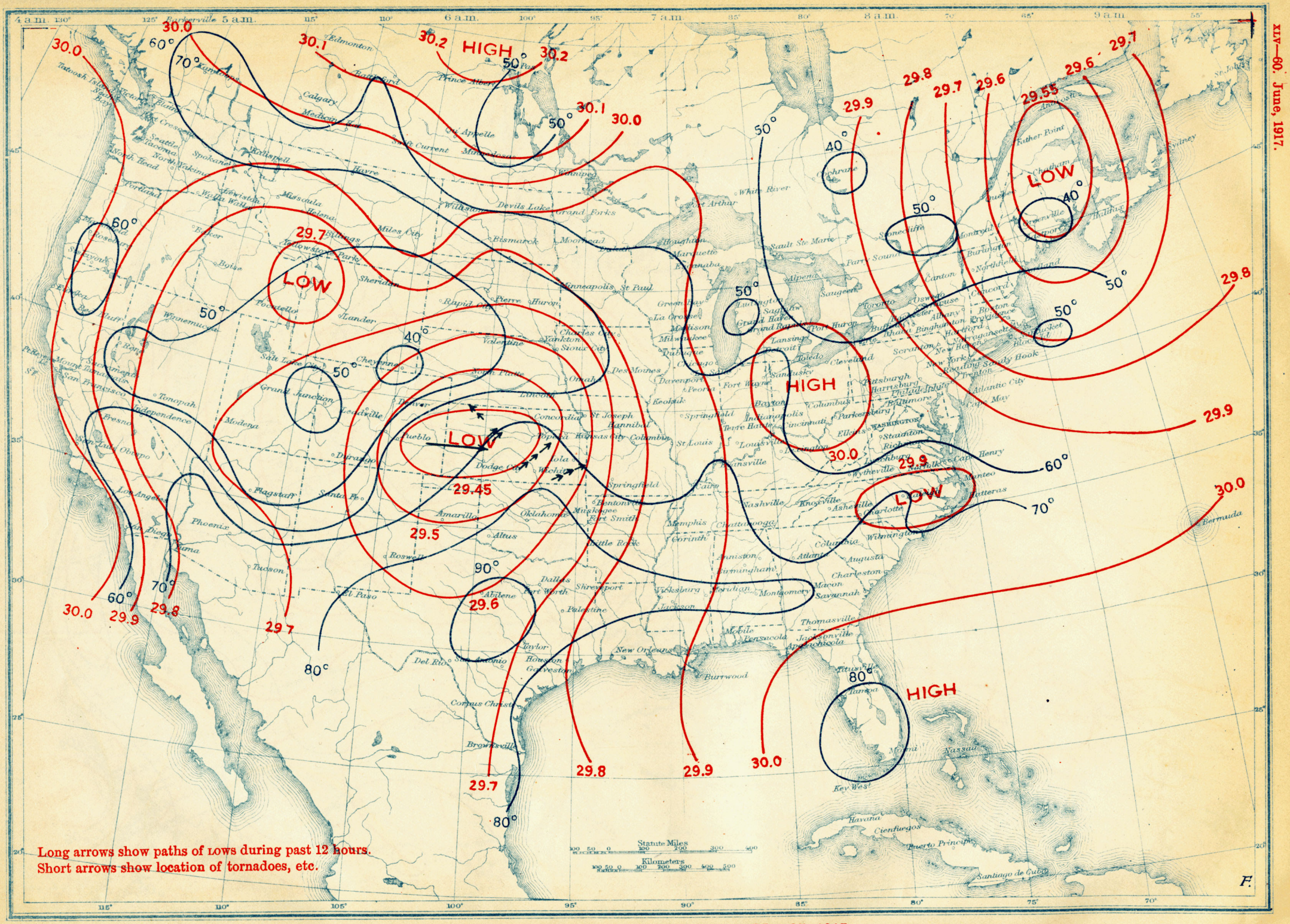
Favorable and unfavorable weather for flying.—Wind; clouds; haze, etc.

II.

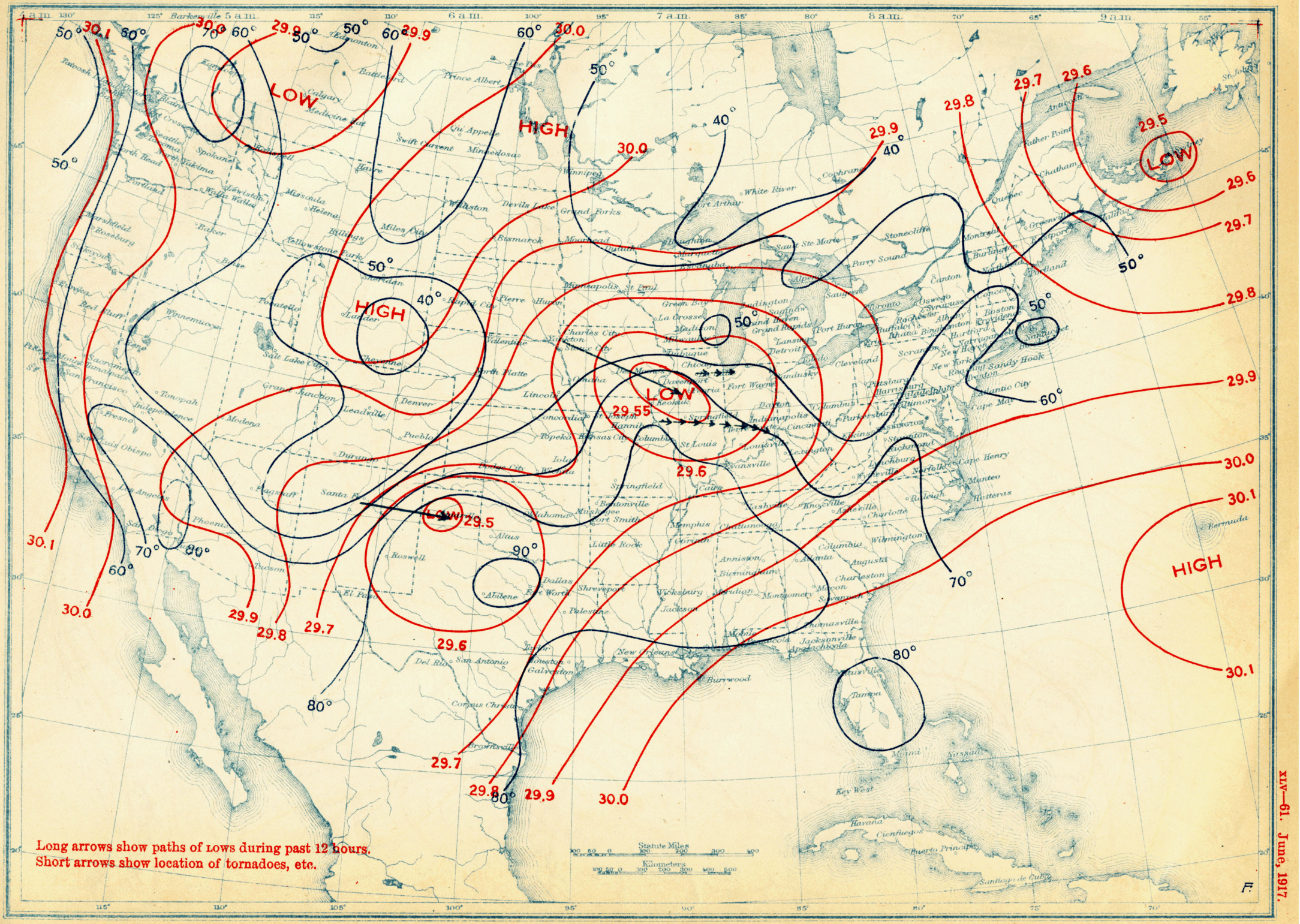
Laboratory Work at Blue Hill Observatory (10 hours). Alexander G. McAdie, Abbott Lawrence Rotch Professor of Meteorology, Harvard University, and Director of the Blue Hill Meteorological Observatory, Readville, Mass.



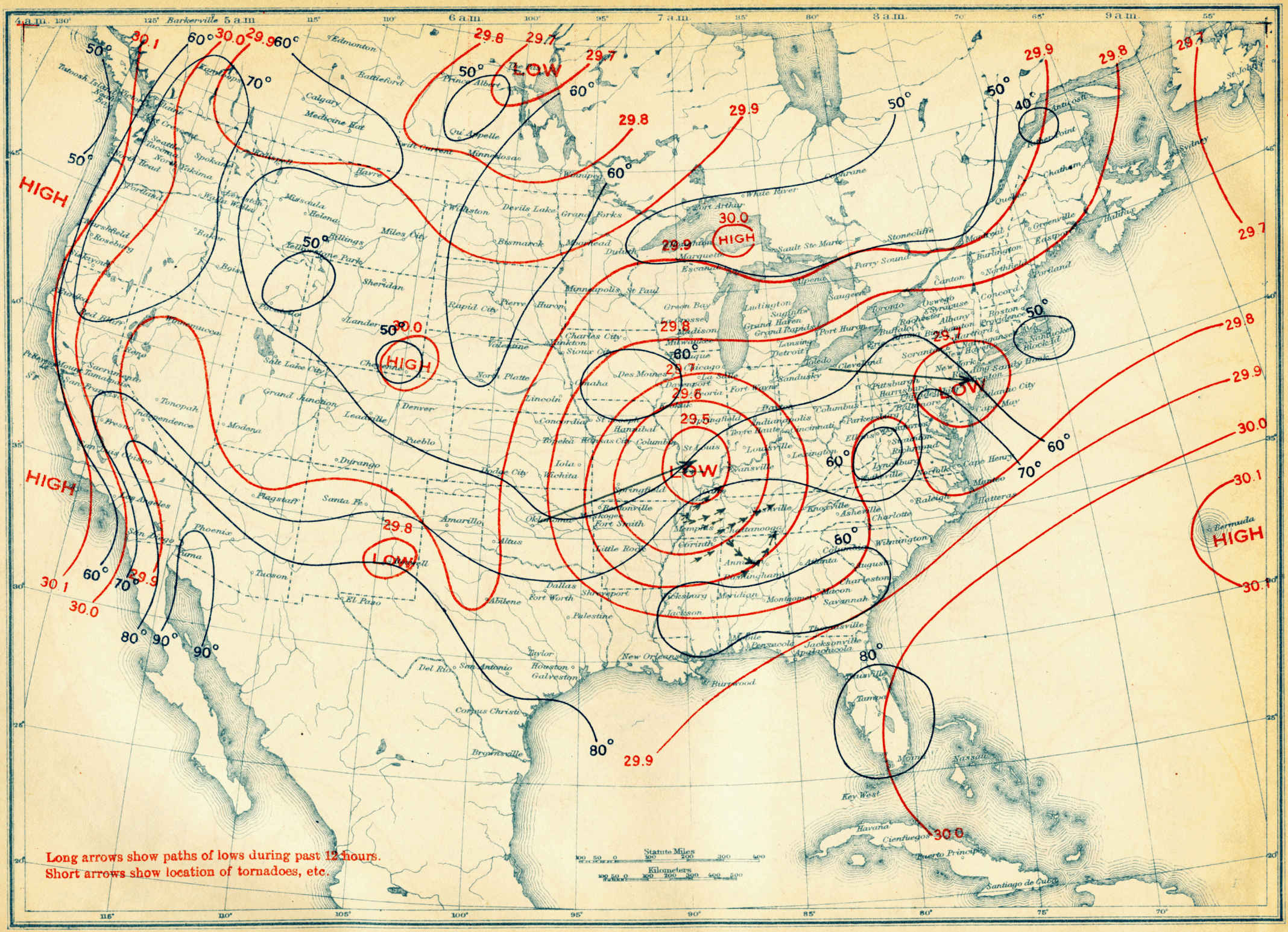
H. C. F. FIG. 4.—Weather Map at 8 p. m., May 20, 1917.



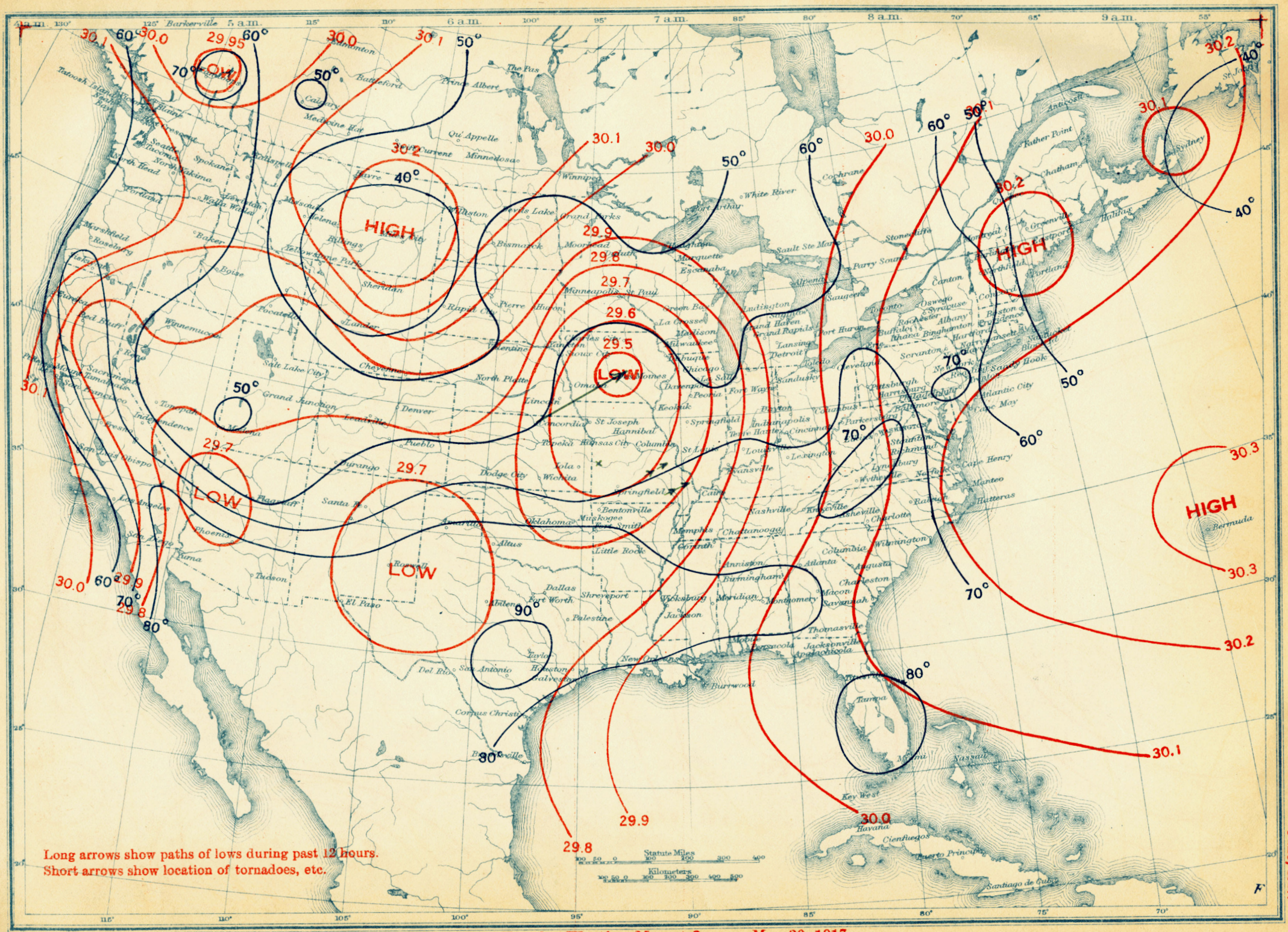
H. C. F. FIG. 5.—Weather Map at 8 p. m., May 25, 1917.



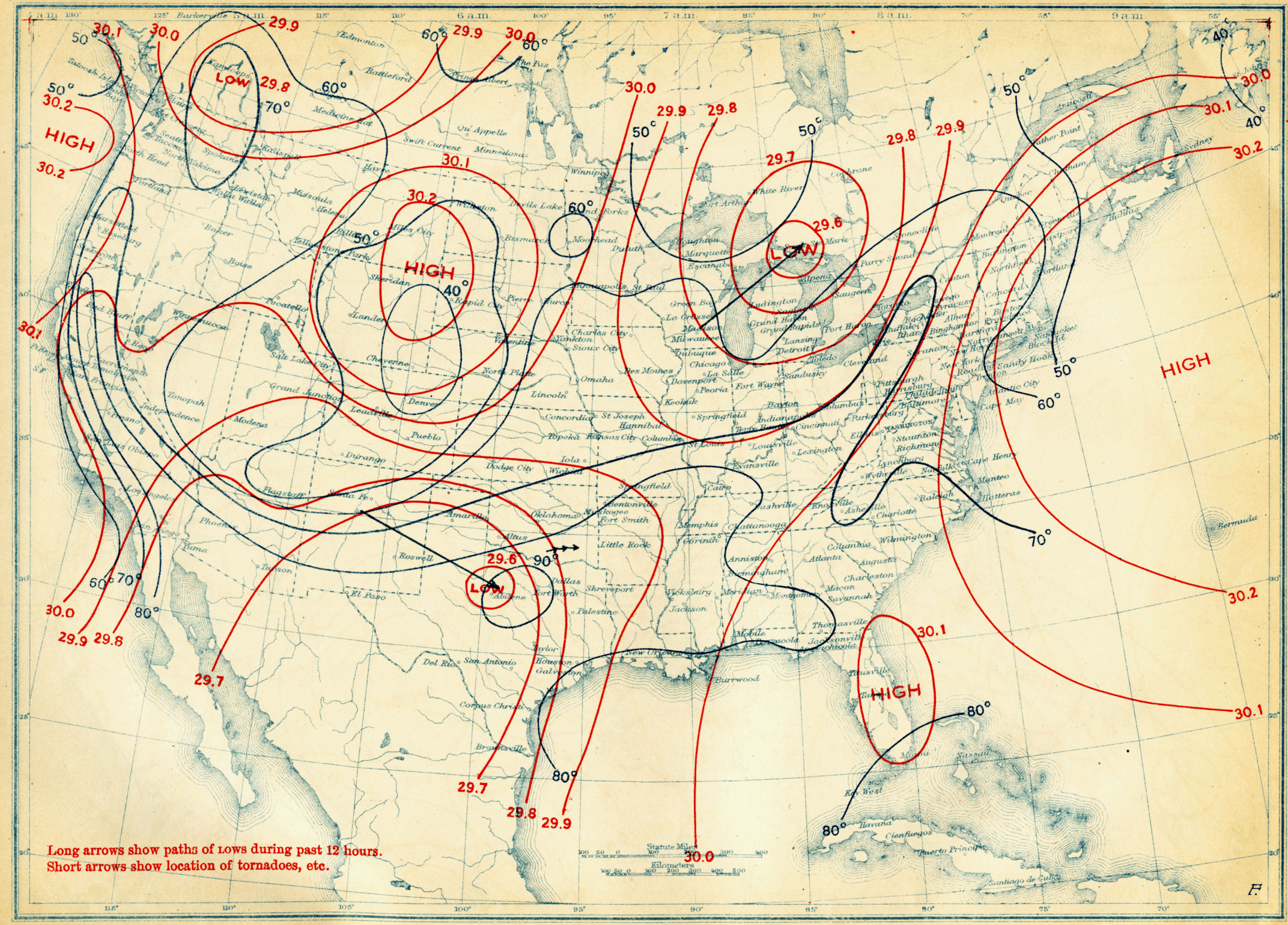
H. C. F. FIG. 6.—Weather Map at 8 p. m., May 26, 1917.



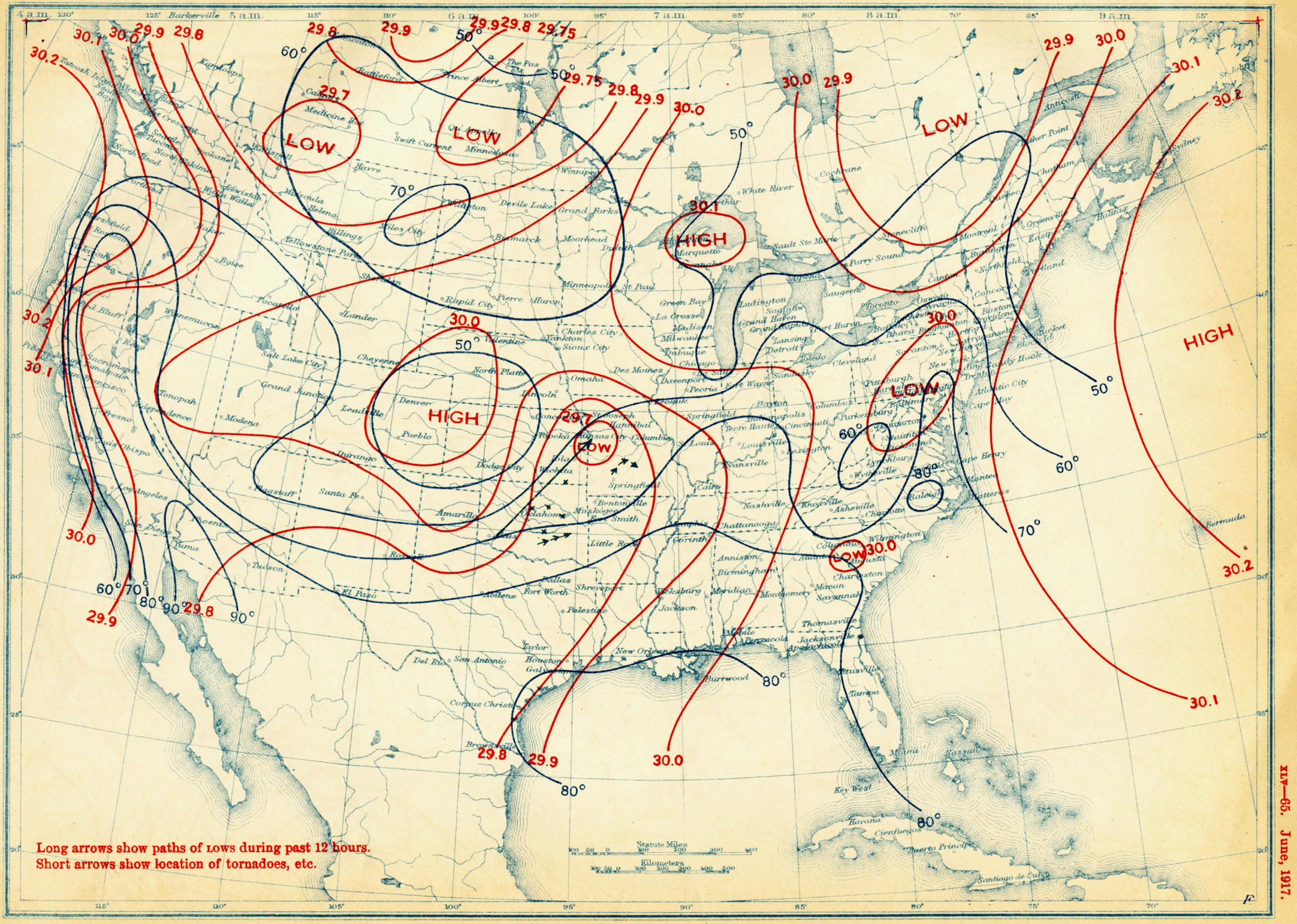
H. C. F. FIG. 7.—Weather Map at 8 p. m., May 27, 1917.



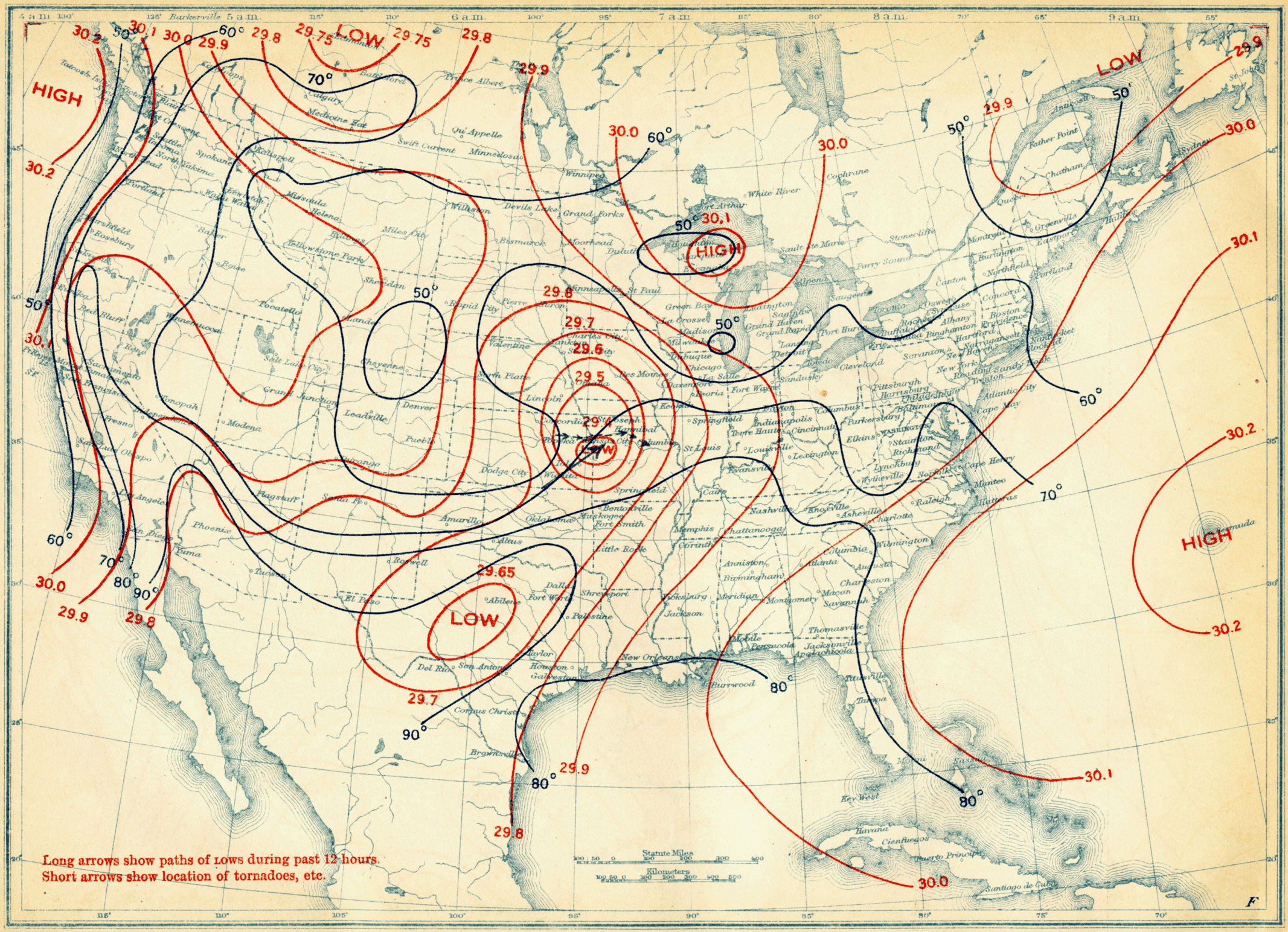
H. C. F. FIG. 8.—Weather Map at 8 p. m., May 30, 1917.



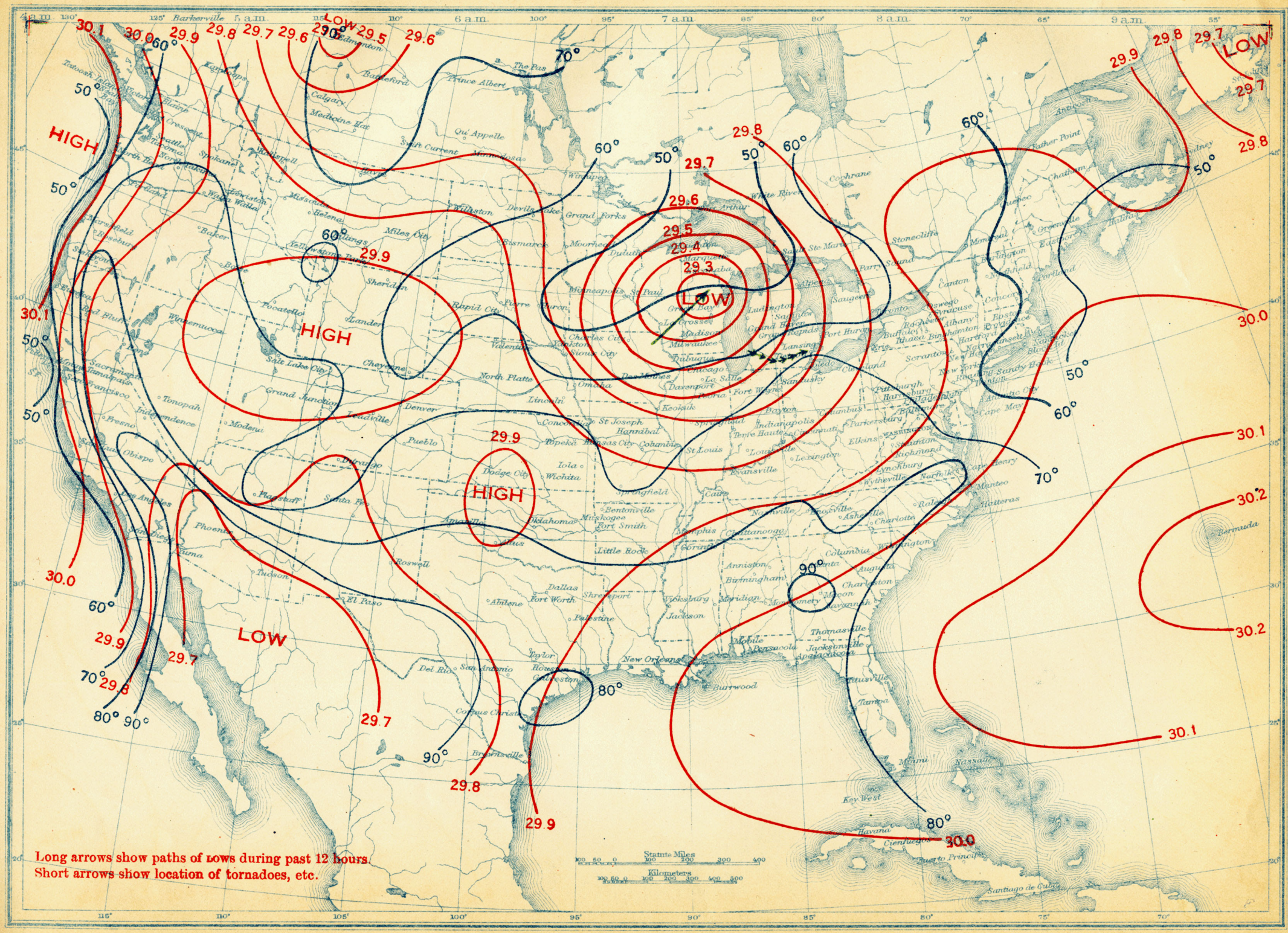
H. C. F. FIG. 9.—Weather Map at 8 p. m., May 31, 1917.



H. C. F. FIG. 10.—Weather Map at 8 p. m., June 1, 1917.



H. C. F. FIG. 11.—Weather Map at 8 p. m., June 5, 1917.



H. C. F. FIG. 12.—Weather Map at 8 p. m., June 6, 1917.